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Abstract. This paper presents a conceptual design approach to the development of a hybrid Knowledge Based (KB) system for Green Manufacturing Management (GMM) at the planning and design stages. The research concentrates on the GMM by using a hybrid KB system, which is a blend of KB system and Gauging Absences of Pre-requisites (GAP). The hybrid KB/GAP system identifies all potentials elements of green manufacturing management issues throughout the development of this system. The KB system used in the planning and design stages analyses the gap between the existing and the benchmark organizations for an effective implementation through the GAP analysis technique. The proposed KBGMM model at the design stage explores two components, namely Competitive Priority and Lean Environment modules. Through the simulated results, the KBGMM System has identified, for each modules and sub-module, the problem categories in a prioritized manner. The System finalized all the Bad Points (BP) that need to be improved to achieve benchmark implementation of GMM at the design stage. The System provides valuable decision making information for the planning and design a GMM in term of business organization.

1. Introduction

The environment has become a critical issue today. This is due to excessive and unjust use of natural resources. Since 40 years ago, several highly visible environmental disasters have demonstrated the importance of having a comprehensive environmental strategy in place [1-5]. Green manufacturing management (GMM) is a management system that contains only required resources and materials, manufactures only required quantity of quality products on time that meet customers' demands which driven the aim to reduce environmental impact. The Center for Green Manufacturing at the University of Alabama defines the goal of green manufacturing as:

"To prevent pollution and save energy through the discovery and development of new knowledge that reduces and/or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products or processes."

In the context of Malaysia, the government has proposed a fund of RM1.5 billion to promote the Green technology in 2010 through the National Green Technology Centre [6]. As are true of Total Quality Management (TQM) and other improvement initiative programmes, environmental strategies must be conceived and supported by top management, but deployed in every functional area of an organization to be meaningful [1]. With current competitive business environment and environment-friendly awareness, management should not only focus on the initiatives such as TQM, lean

manufacturing, performance measurement, and supply chain but also the sustainability aspects of the initiatives.

2. Research Background
This paper introduces a new concept called Collaborative Green Manufacturing Management (CGMM) which can be implemented as an alternative for any manufacturer to improve their lean and green manufacturing processes. In the CGMM chain, all members must work together towards common objectives in order to make the lean and green manufacturing achievable in the collaborative environment. The framework presented consists of the conceptual design of the proposed CGMM system. The conceptual model is then converted into the structure of Knowledge-Based Collaborative Green Manufacturing Management System (KBCGMM) to enable the use of knowledge based system (KBS) which embed two powerful techniques; Gauging Absences of Pre-Requisites (GAP) and Analytical Hierarchy Process (AHP).

GAP analysis is a technique that is used to assess the gap between the organisation's actual environment and an ideal one, resulting in knowledge of the desirable prerequisites for an effective implementation [7-8]. On the other hand, AHP first developed and introduced by Saaty [9], is a powerful tool, which can be used to deal with multi-attribute and complex problems particularly in selecting and prioritising an alternative for improvement purposes. AHP has the capability to weigh the alternatives and make a comparison amongst the alternatives before the optimum solution can be suggested. However, in this paper, only the application of GAP technique will be shown and discussed.

2.1. Planning stage
The planning stage requires information that needs to be considered which focuses on two main aspects as shown in figure 1; the Collaborative Business and Green Manufacturing Chain perspectives. The function for the first part of planning stage, Collaborative Business is for gathering general information about the organisations environment, financial and market status. Organisation environment determines the particular environment the company is operating in. The information needed in this module are size of company, annual sales turnover, number of employees, age of company, position of company in automotive chain, competitors, suppliers, customers, and investment in green manufacturing activities. In CGMM, the position of a company in the supply chain is required to determine its suppliers and customers, since emphasis in not only within the organisation (internal), but also between organisations (external).

In the second part of planning stage, Green Manufacturing Chain component refers to connections between any two value-adding activities inside and across organisations. Activity in any process can be allocated as value-adding or non-value adding. In lean and green manufacturing, non-value adding activity is considered as a waste and must be eliminated. Green Manufacturing Chain can be divided into three subcomponents, Internal Chain, External Chain, and Product Design for Manufacture. In the Internal Green Chain, operators of the next process are the customers, and suppliers (current process) are committed to supply parts which are good in quality at the right time and right quantity. Customer satisfaction and supplier commitment are two major elements which contribute to the success of the internal green chain. In the External Green Chain, suppliers are considered as partners instead of outsiders. Suppliers are well informed about the demand and planning of the organisation and sometimes invited to involve in the product development and process design. The Product Design for Manufacture is developed with objectives of gathering product design information and analysing the product design process which covers from the conceptual design to the full launch of new products.

2.2. Design stage

The design stage requires information that needs to be considered which focuses on two main aspects as shown in figure 1; the Organization Competitive Priority and Lean Environment perspectives. The function of modules in Organization Competitive Priority is to discover the current organization capability towards CGMM in terms of these five competitive priorities i.e. quality, time, value, flexibility, and supply chain.

In the second part of design stage, Lean Environment component refers to connections between any two value-adding activities inside and across organizations. Activity in any process can be allocated as value-adding or non-value adding. In lean and green manufacturing, non-value adding activity is considered as a waste and must be eliminated.   Lean Environment can be divided into three subcomponents, Employee Involvement, Waste Elimination, and Kaizen. The objective of this level is to identify and evaluate the current organisation CLMM alignment, which is based on these three identified processes to achieve customer satisfaction.
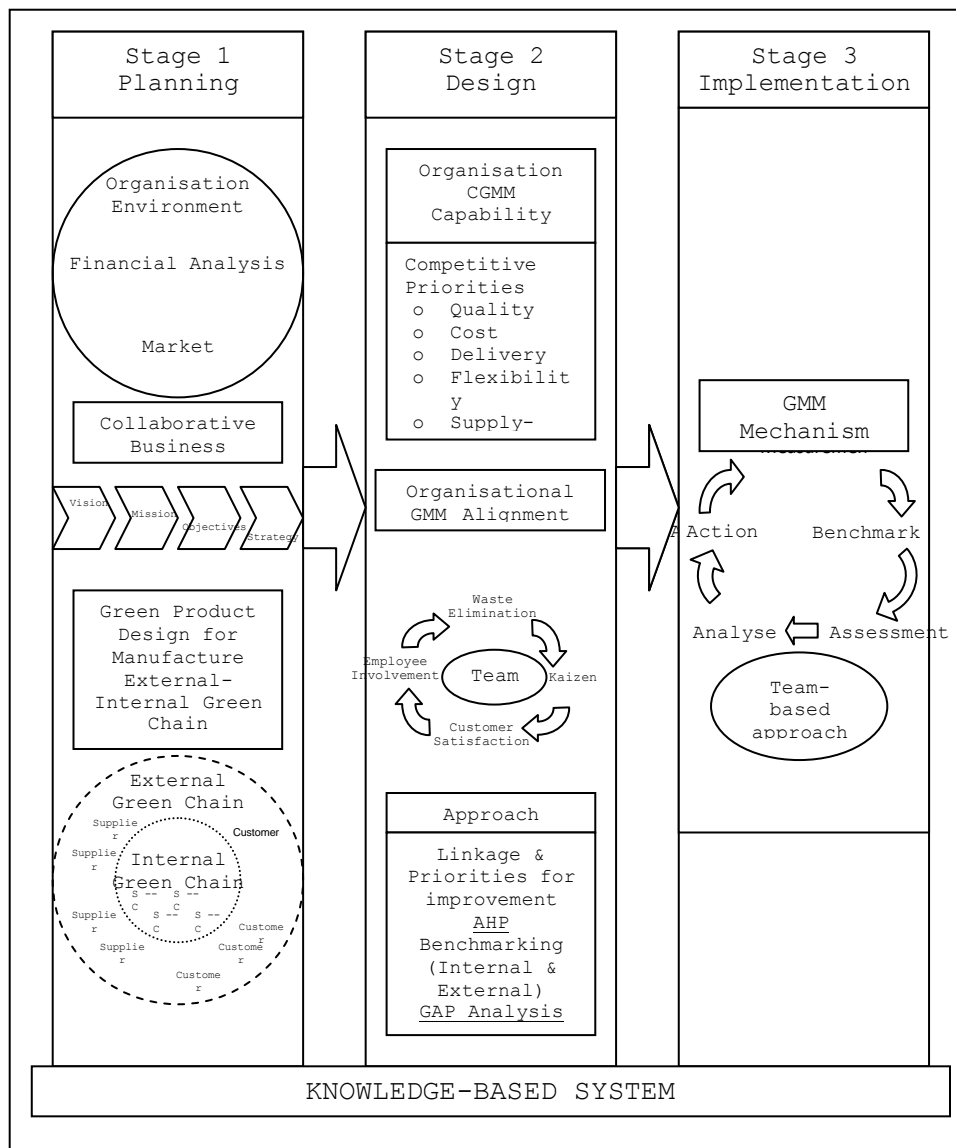

Figure 1. Planning and Design stages of KBCGMM conceptual model.

3. Example of Model Development

As an example, the Product Design for Manufacture Module (Level 2 of the KBCGMM System) is used to illustrate how the model was developed using KBS. Product design is one of the main activities of any manufacturing company, beside physical production and order taking process [10]. The Product Design for Manufacture module was developed with objectives of gathering product design information and analysing the product design process which covers from the conceptual design to the full launch of new products. Figure 2 shows two questions from this module which was developed using AM for Windows® software.
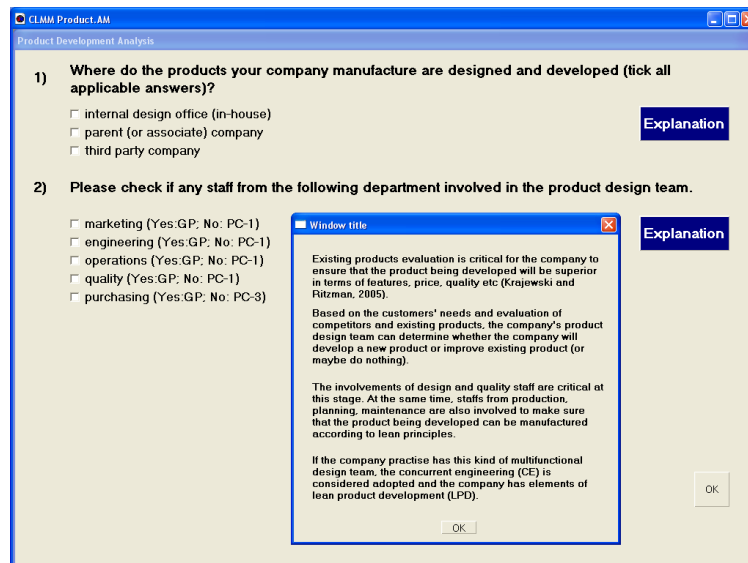
Figure 2. Example of questions in the Product Design for Manufacture Module.

A brief example of rules used in question number two is as follows:

IF the marketing team involved in the product design (Yes: GP; No: PC-1)
AND the engineering team involved in the product design (Yes: GP; No: PC-1)
AND the operations team involved in the product design (Yes: GP; No: PC-1)
AND the quality team involved in the product design (Yes: GP; No: PC-1)
AND the purchasing team involved in the product design (Yes: GP; No: PC-3)
THEN the product design team is multifunctional and the company design activity is good
ELSE the product design team is isolated and the company design activity needs improvement

An explanation facility is also provided in the system in order to assist the users in understanding the questions. Figure 3 shows two questions from this module which was developed using AM for Windows® software.

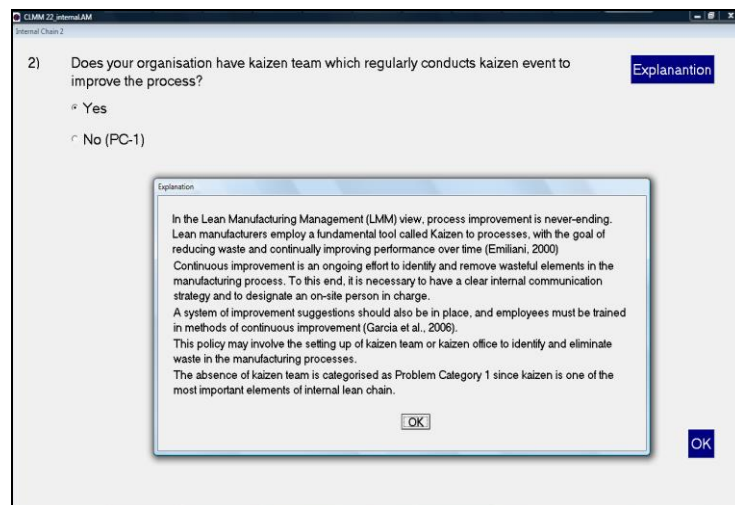**Figure 3.** Example of explanation facility in the system.

Many of the questions are used with the GAP Analysis and are indicated by either Good Point (GP) code or Bad Point (BP) with problem categories code (PC-1 to PC-9). The description of the code is as described by Mohamed and Khan [11] and as shown in table 1.

Table 1. Problem categories and description of GAP analysis technique

Category	Description
PC-1	This indicates a **very serious problem**, which should and can be resolved in the short term and the result of the problem is quite likely to provide a real short-term benefit.
PC-2	This indicates a **serious problem**, which involves **pre-requisites to the system** and requires appropriate and logical improvement and implementation plan.
PC-3	This indicates a **major problem**, which is likely to have **pre-requisites to the system** and is better dealt with as part of an appropriate and logical improvement and implementation plan.
PC-4	This is **quite a major problem**, which is likely to have **pre-requisites to the sub-system** and is better dealt with as part of an appropriate and logical improvement and implementation plan.
PC-5	This indicates a **problem** and can be dealt with now. If resolved, it is likely to produce short-term benefits.
PC-6	This indicates a **minor problem** and can be dealt with now. If resolved, it is likely to produce short-term benefits.
PC-7	This is **not a serious problem**. Although it could be dealt with now, it is unlikely to produce short-term benefits. Therefore, it should only be dealt with if it is a pre-requisite for other things.
PC-8	This is **not really a problem**, However it is important to consider certain situations as future improvement.
PC-9	This is not **really a Good or Bad** point itself. The questions associated with this category are primarily asked to identify certain situations in the environment, which upon subsequent probing by succeeding questions may well reveal problems.

By answering the questions, the missing pre-requisites of the manufacturer position in relative to the benchmark can be identified through the number of Bad Points and its PC number. In order to evaluate the system performance and consistency, the prototype of CGMM model for the design stage has been tested by using artificial data. A simulated result for KBCGMM System – Stage 2 (design) is shown in Table 2.

Table 2. Example of summarized results of the GAP Analysis for the Design Stage

Module (and Sub-module)	No of Questions	GP	BP	GAP Analysis								
				PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9
COMPETITIVE PRIORITY												
Quality												
Supply Quality Audit	18	10	8	2	1	0	2	1	0	1	1	0
Main Production Quality Audit	20	13	7	1	1	1	2	2	0	0	0	0
Customer Quality Audit	19	14	5	2	1	0	2	0	0	0	0	0
Sub-total	**57**	**37**	**20**	**5**	**3**	**1**	**6**	**3**	**0**	**1**	**1**	**0**
Cost												
Supply Cost	17	9	8	2	1	1	2	0	2	0	0	0
Main Production Cost	15	8	7	1	0	1	0	1	2	2	0	0
Resource Cost	12	6	6	1	1	0	3	0	0	1	0	0
Sub-total	**44**	**23**	**21**	**4**	**2**	**2**	**5**	**1**	**4**	**3**	**0**	**0**
Delivery												
Supply Timing	14	9	5	1	0	1	0	2	1	0	0	0
Main Production Timing	11	7	4	1	0	1	0	2	0	0	0	0
Delivery Timing	11	7	4	1	0	1	0	0	2	0	0	0
Sub-total	**36**	**23**	**13**	**3**	**0**	**3**	**0**	**4**	**3**	**0**	**0**	**0**
Flexibility												
Supply Flexibility	12	6	6	2	1	0	2	0	0	0	0	1
Main Prod Flexibility	12	8	4	1	1	0	0	0	0	1	1	0
Delivery Flexibility	11	6	5	1	1	0	1	0	0	1	0	1
Sub-total	**35**	**20**	**13**	**4**	**3**	**0**	**3**	**0**	**0**	**2**	**1**	**2**
Supply Chain												
Location	15	10	5	2	0	0	1	0	1	0	1	0
Logistics	17	12	5	0	2	0	1	1	1	0	0	0
Sub-total	**32**	**22**	**10**	**2**	**2**	**0**	**2**	**1**	**2**	**0**	**1**	**0**
LEAN ENVIRONMENT												
Employee Involvement												
Measurement	12	9	3	1	0	0	0	2	0	0	0	0
Benchmark	15	7	8	2	0	1	0	1	1	1	1	1
Assessment	10	4	6	0	1	1	1	2	1	0	0	0
Analyze	12	4	8	1	0	2	0	1	1	1	1	1
Action	12	8	4	1	1	0	1	1	0	0	0	0
Sub-total	**61**	**32**	**29**	**5**	**2**	**4**	**2**	**7**	**3**	**2**	**2**	**2**
Waste Elimination												
Measurement	13	7	6	1	0	2	0	1	0	1	0	1
Benchmark	14	6	8	1	1	0	2	0	2	1	1	0
Assessment	11	5	6	0	1	1	0	1	0	1	1	1
Analyze	10	5	5	1	0	1	0	1	1	1	0	0
Action	12	7	5	0	1	0	1	1	1	1	0	0
Sub-total	**60**	**30**	**30**	**3**	**3**	**4**	**3**	**4**	**4**	**5**	**2**	**2**
Kaizen												
Measurement	13	8	5	1	0	1	0	1	1	1	0	0

Benchmark	17	8	9	2	1	1	1	1	1	0	1	1
Assessment	16	9	7	1	0	1	1	2	0	2	0	0
Analyze	11	7	4	0	1	0	1	0	1	0	1	0
Action	14	10	4	1	0	1	0	1	1	0	0	0
Sub-total	**71**	**42**	**29**	**5**	**2**	**4**	**3**	**5**	**4**	**3**	**2**	**1**
GRAND TOTAL	**395**	**229**	**166**	**31**	**17**	**18**	**24**	**25**	**20**	**16**	**9**	**7**

A total number of 395 questions have been asked in this stage which also contains the number of Good Points (GP), the number of Bad Points (BP), together with the Problem Categories (PC) of the BP. The GAP analysis optimization technique suggests that only the BP are categorized into PC in order to identify the necessary pre-requisites that are required to achieve the CGMM. The KBGMM System has identified, for each modules and sub-module, the problem categories in a prioritized manner. Out of 395 questions, 229 have been categorized as GP whereas 166 have been considered as BP. The System finalized these 166 BP (31 PC-1, 17 PC-2, 18 PC-3, 24 PC-4, 25 PC-5, 20 PC-6, 16 PC-7, 9 PC-8, and 7 PC-9) need to be improved to achieve benchmark implementation of CGMM.

4. Conclusion

This paper has described the importance for automotive manufacturers to implement GMM in order to improve their lean and green manufacturing management system and compete in the globalize competition. A conceptual model for the design stage of GMM is developed and presented. The conceptual model then is converted into the structure of KBGMM which is supported by the knowledge based system (KBS). At the same time, Gauging Absences of Pre-Requisites (GAP) Analysis technique which is incorporated in the system assists users to understand the position of their organization in comparison to the ideal one. This would not only support in implementing GMM but also in benchmarking the strength of organizations in this area.

Acknowledgement

References

[1]   Walton S V, Handfield, R B and Melnyk, S A 2008 *J. Supply Chain Management.* **34** 2
[2]   Garg H K and Singh R 2013 *Inter. J. Automot. Mech. Eng.* **7** 983
[3]   Andrew-Muno M and Ibrahim R N 2013 *J Mech Eng Sci* **4** 488
[4]   Mohamed N M Z N and Khan M K 2012 *Inter J Automot Mech Eng* **5** 545
[5]   Rose M A N M, Deros B M and Rahman M N A 2013 *Inter J Automot Mech Eng* **7** 820.
[6]   Razak M N 2009 *The 2010 Budget Speech* (Kuala Lumpur: Ministry of Finance Malaysia)
[7]   Udin Z M 2004 *A Hybrid Knowledge-Based Approach for Planning and Designing a Collaborative Supply Chain Management System.* (Bradford: University of Bradford)
[8]   Wibisono D 2003 *A Knowledge Based Approach to Assist in the Design of a Performance Measurement System for a Manufacturing Environment* (Bradford: University of Bradford)
[9]   Saaty T L 1980 *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation* (New York: McGraw-Hill)
[10]   Womack J P and Jones D T 2003 *Lean Thinking: Banish Waste and Create Wealth in Your Corporation* (New York: Simon and Schuster)
[11]   Mohamed N M Z N and Khan M K 2011. *Proc. of 26th Int. Conf. on CAD/CAM, Robotics and Factories of the Future 2011* (Kuala Lumpur) p 310